Neogene Stratigraphic Development of the Arabian (Persian) Gulf

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LONG TERM GOALS

The Arabian Gulf is a shallow (<100 m), epicontinental sea connected to the Gulf of Oman through the Straits of Hormuz. This basin, besides being an important military, economic, and political region, serves as an excellent model for sequence stratigraphic studies of an arid littoral environment. Neogene sediments in the Gulf comprise a northeast-thickening wedge (0.1-2.0 km) of clastics shed from the Zagros uplift in Iran. Our long-term goal is to understand how variations in sediment source, tectonic subsidence, climate, and sea level affected sedimentary processes and stratigraphic development of an arid, shallow-marine environment.

OBJECTIVES

The Persian/Arabian Gulf is subsiding in response to the collision during the last 5-10 Myrs between the Arabian and Asian plates and to growth of the Zagros mountains. Uplifted foldbelts, thickened continental crust, and poorly understood subcrustal loads depress the northeast edge of the Arabian plate creating, by flexure, a foreland basin that is filled to the southeast with the shallow Gulf sea and filled to the northwest with sediment deposited by the Mesopotamian river system. The stratigraphy of Neogene sediments within the Gulf is clearly affected by the tectonics of the collision and mountain building. Our previous work in the Arabian Gulf revealed an unconformity dipping to the northeast towards Iran (Ross et al., 1986). This unconformity was interpreted to be the base of the foreland basin sediment sequence shed from the rising Zagros range. Our objective this year was to map the variability in depth to the horizon and to understand how tectonics of collisional plate boundaries and deformation of continental crust controls the stratigraphic development of these sediments and, thus, their physical properties.

APPROACH

Our approach was to map Neogene stratigraphy with seismic reflection profiles and tie this structure to lithology and dates from industry wells where possible. To try to obtain an explanation for the nature and geometry the foreland basin unit, most of our effort was put into a study of the neotectonics of the Zagros. We hoped to determine how lateral variations along the range affected patterns of sediment supply to the basin and the tectonic component of subsidence.

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14. ABSTRACT

The Arabian Gulf is a shallow (<100 m), epicontinental sea connected to the Gulf of Oman through the Straits of Hormuz. This basin, besides being an important military, economic, and political region, serves as an excellent model for sequence stratigraphic studies of an arid littoral environment. Neogene sediments in the Gulf comprise a northeast-thickening wedge (0.1-2.0 km) of clastics shed from the Zagros uplift in Iran. Our long-term goal is to understand how variations in sediment source, tectonic subsidence, climate, and sea level affected sedimentary processes and stratigraphic development of an arid, shallow-marine environment

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WORK COMPLETED

In the past year we interpreted the MCS profiles from the 1998 USNS Bowditch cruise. We integrated these results with those from our interpretation of the 1977 R/V Atlantis II and industry profiles and tied the seismics to the few industry wells for which we had geologic data (Swift et al., 1998). We used an average velocity-depth function from well check-shot surveys to compute sediment thickness. We prepared maps of depth to the youngest horizons that can be correlated throughout the basin. These horizons precede the initiation of mountain building by 6-10 Ma, but the intervening sediment units are relatively thin. So, the horizons provide a good marker for the start of foreland basin subsidence. No reflections in the overlying basin sequence can be traced laterally for more than 50-100 km and, thus, can not be mapped with our line spacing. Lateral variations along the Zagros were studied by defining tracks perpendicular to the range and foreland basin and extracting topographic size, shape, and location parameters from a data base that included the USGS 30 sec land elevation compilation and water depths from several sources. Geophysical data included gravity data from BGI in Paris and earthquake hypocenters from the Iris ISC catalog and smaller, more-reliable relocations done by Engdahl, Maggi, and others. Maps of geothermal gradient were obtained from Iran. Published seismic surveys in Iran and Iraq and geologic descriptions from industry maps and published literature were compiled.

RESULTS

Most sediments down to 0.6-1.2 km depth beneath the Gulf are comprised of shallow marine sands and marls thickening northeastward towards Iran. The seismic section in Figure 1a shows a prominent reflection/unconformity, dipping from 0.2 sec on SW to 1.1 sec on the NE, that correlates in one well to the top of the Asmari limestone with age of Early Miocene. The horizon appears to be time-transgressive, because the reflection elsewhere appears to represent the top of Lower Fars units (anhydrite, salt, shale, or carbonate beds) that were deposited in middle and early-late Miocene. Underlying reflections correlate to carbonate units deposited during stable epi-continental sea conditions. The overlying wedge unit is comprised primarily of units with poor lateral correlation that thin to the southwest. In general, these sediments are finer-grained and include more terrigenous clastic material than the pre-Asmari sequence. Accumulation rates are much higher. As a result, seismic velocities beneath the Gulf decrease towards the northeast (Figure 1b). Throughout the Gulf the base of the foreland basin sedimentary unit dips down towards the northeast (Figure 2). Tectonic depression of the crust beneath the Gulf, however, has not been uniform during the last 5-10 Ma: the dip of the reflector and the thickness of the wedge near the Iranian coast increase northwestward. This trend is a result of variations in style of deformation in the Zagros range.

In general, structural features in the Zagros trend NW-SE parallel to the plate suture zone. This trend is broken by two embayments of lower topography that, not coincidentally, include the bulk of the Iraqi and Iranian oil reserves. The origin of these embayments and their implications for subsidence in the Gulf were poorly resolved prior to this investigation. These features have been attributed to syntaxies in plate convergence and to locations where the absence of a salt layer overlying basement reduced folding.

Our mapping suggests that the deformation of the Zagros (and, as a result, the structural and stratigraphic history of deposits in the foreland basin) is controlled by processes of shortening deep within the continental crust. Variations in the width of the foreland basin (ie. the Gulf) do not correlate with the cross-sectional area or width of the Zagros range. We infer that the width of the basin depends on the deep structure of the Arabian plate boundary beneath the suture zone that can not

be resolved with present data. In contrast, the thickness of the basin fill appears to be controlled by patterns of crustal deformation. All earthquakes occur within the crust, and their distribution parallels topography, ie. few earthquakes occur in the lowlands of the topographic embayments. Horizons within the Gulf and Mesopotamian plain deepen adjacent to the embayments and shallow in front of the intervening foldbelts, but there is no corresponding change in the width of the foreland basin. This lack of correlation indicates that basement subsidence is not a simple function of loading and flexure of the plate edge. The dichotomy in topographic profiles between embayments and foldbelts can be correlated to profiles created when the crustal shortening is modeled with and without a low viscosity layer in the lower crust (Royden, 1996). The observed lateral variability in topography of the Zagros range - and, thus, the stratigraphic development within the foreland basin - developed in response to variations in lower crustal rheology with lateral scales of 300-400 km.

IMPACT/APPLICATIONS

Foreland basin tectonics controls the nature of Gulf sediment and its accumulation rate. These in turn control the physical and acoustic properties of the seafloor and the upper 1-2 km of sediment (eg. Figure 2). Propagation of low-frequency sound in the upper 1 km beneath the Gulf is slower near Iran than near Arabia, and this affect is more pronounced closer to Iraq. Scientifically, we show that inhomogeneities in lower continental crust rheology affect subsidence in a foreland basin and, thus, basin stratigraphy. It is possible that similar inhomogeneities occur elsewhere along the edges of continents and affect sediment patterns on continental shelves and slopes.

TRANSITIONS

These results - and others that we prepare as we progress with this project - will be transitioned to our colleagues at NAVOCEANO for their use in preparation of data bases in support of fleet operations.

RELATED PRODUCTS

The high-resolution seismic and seafloor mapping results provide an arid environment end-member to the STARTIFORM field studies.

REFERENCES

Royden, L., 1996, Coupling and decoupling of crust and mantle in convergent orogens: implications for strain partitioning in the crust, J. Geophys. Res., 101, 17679-17705.

Ross, D.A., E. Uchupi, and R.S. White, 1986, The geology of the Persian Gulf-Gulf of Oman region: a synthesis, Rev. Geophys., 24, 537-556.

Swift, S.A., E. Uchupi, and D.A. Ross, 1998, Late Cenozoic geology of the central Persian (Arabian) Gulf from industry well data and seismic profiles, Woods Hole Oceanographic Technical Memorandum, WHOI-01-98, 75 pp.

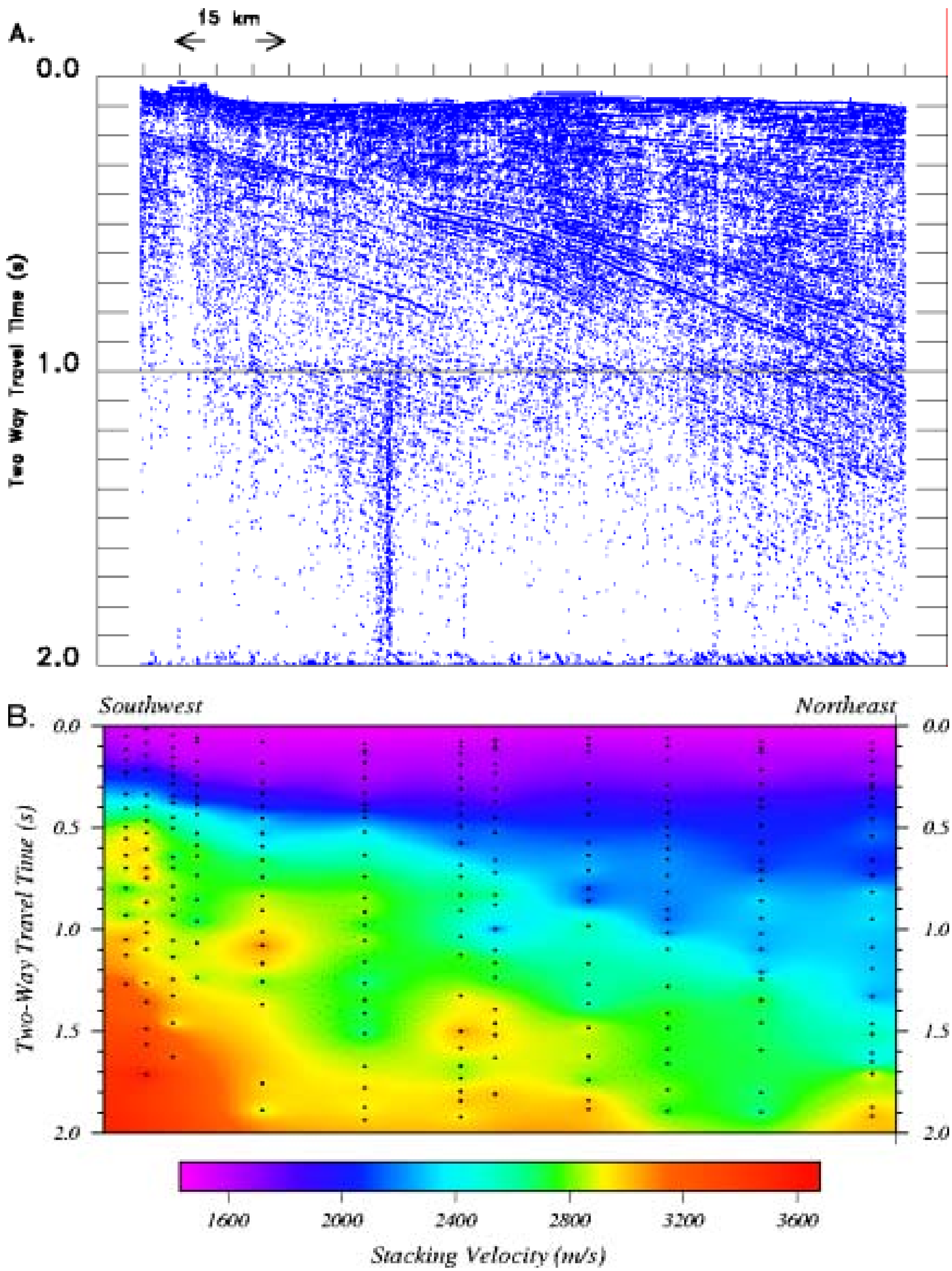

Figure 1. Foreland basin sediments, with low seismic velocities, increase in thickness from ~0.2 km off Arabia to ~1 km off Iran. (a) Seismic profile extends northeastward from the edge of carbonate bank off Qatar to within ~15 km off Iran. (b) Stacking velocities computed during MCS processing (dots) are up to 0.5 km/s slower in the foreland basin wedge.

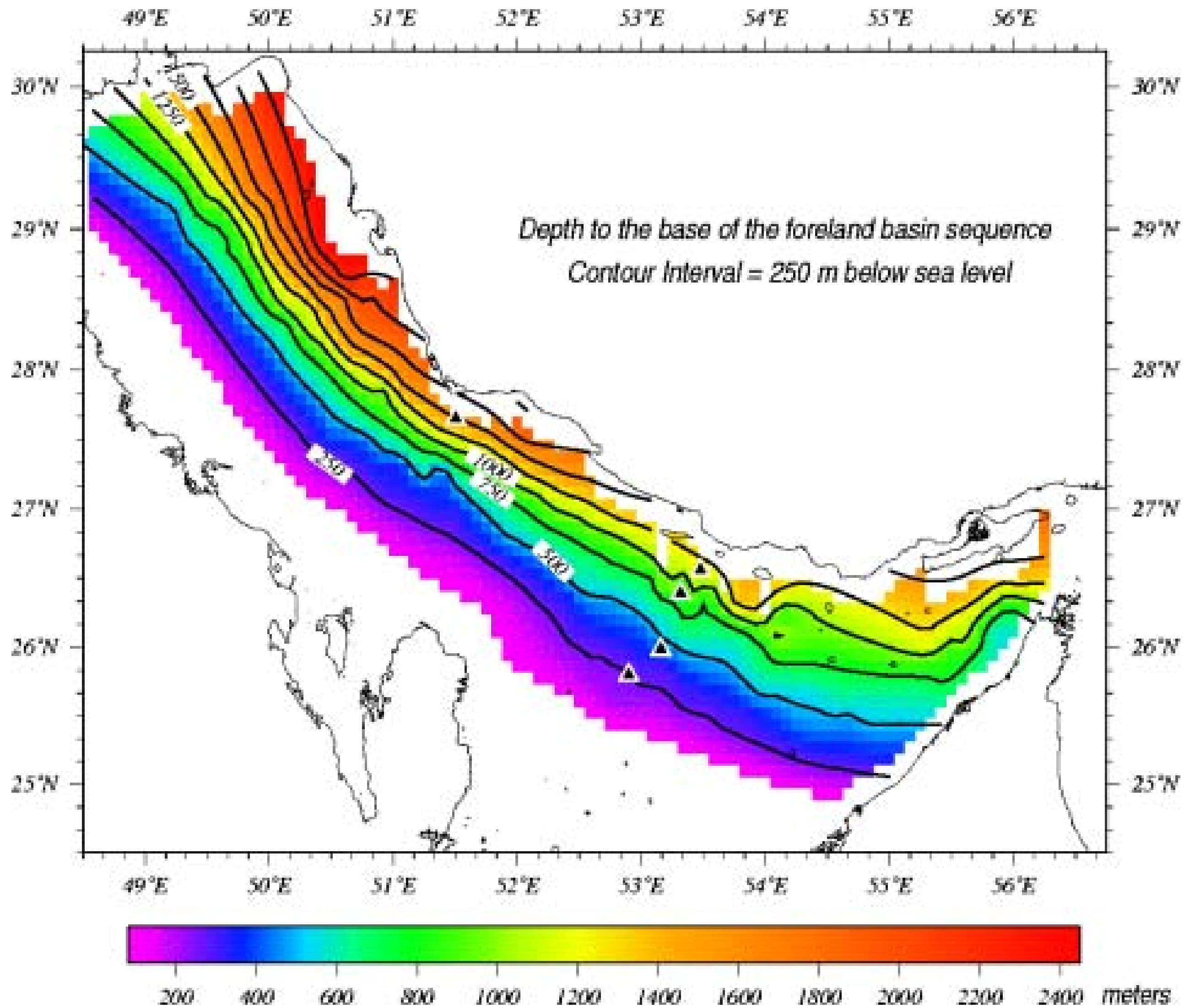

Figure 2. The base of the foreland basin wedge dips northeastward from about 100 m below sea level off Arabia. The depth to the base of the wedge off Iran increases from about 1250 m near Laven Island in the southeastern portion of the Gulf to 2250-2500 m off Kharg Island in the northwestern Gulf. Depths were compiled from seismic reflection surveys. Triangles indicate locations of five industry wells to which we could tie the mapped horizon and obtain geologic control. Increase in dip towards the northwest reflects a change in nature of deformation processes in the lower continental crust due to the Zagros collision.